

CLAIMS

We claim:

- 1 1. A system comprising:
2 a wavelet-based image processing path to enhance an input image in
3 a wavelet domain; and
4 a print engine coupled to the processing path.
- 1 2. The system defined in Claim 1 wherein the image processing
2 path comprises:
3 a forward wavelet transform;
4 one or more wavelet-based processing blocks; and
5 an inverse wavelet transform.
- 1 3. The system defined in Claim 2 wherein the forward wavelet
2 transform comprises a critically sampled wavelet transform.
- 1 4. The system defined in Claim 2 wherein the forward wavelet
2 transform comprises an overcomplete wavelet transform.

1 10. The system defined in Claim 1 wherein the image processing
2 path comprises:
3 a forward wavelet transform;

4 a denoising processing block coupled to the forward wavelet
5 transform to perform denoising based on at least one given threshold; and
6 an inverse wavelet transform.

1 11. The system defined in Claim 10 wherein the denoising
2 processing block sets coefficients below the at least one given threshold to a
3 predetermined value less than the threshold.

1 12. The system defined in Claim 11 wherein the at least one given
2 threshold is calculated based on the presence of additive Gaussian white
3 noise in an image.

1 13. The system defined in Claim 11 wherein the at least one given
2 threshold is calculated from a series of test images.

1 14. The system defined in Claim 11 wherein the at least one given
2 threshold comprises different thresholds applied to different levels of
3 decomposition.

3 values of H/HL/HH coefficients at a first level at a particular level to create
4 a band dependent threshold.

1 21. The system defined in Claim 11 wherein the at least one given
2 threshold is set based on a standard deviation or medium of absolute values
3 of LH/HL/HH coefficients at each level.

1 22. The system defined in Claim 11 wherein the at least one given
2 threshold is set manually using controls on a user interface.

1 23. The system defined in Claim 11 wherein the at least one given
2 threshold is set by computing local variances/mediums of coefficients in
3 between a band.

1 24. The system defined in Claim 11 wherein the at least one given
2 threshold is set using a classifier.

4 where R is a renormalization factor and α is the parameter that determines
5 the degree of sharpening or smoothing.

1 29. The system defined in Claim 26 wherein the sharpening or
2 smoothing processing block normalizes coefficients after sharpening or
3 smoothing.

1 30. The system defined in Claim 28 wherein the sharpening or
2 smoothing processing block uses a scale dependent factor that is selected to
3 include normalization.

1 31. The system defined in Claim 1 wherein the image processing
2 path comprises a linear interpolation filter that is applied to wavelet
3 coefficients.

1 32. The system defined in Claim 31 wherein the image processing
2 path comprises:
3 an inverse wavelet transform to inverse transform coefficients down
4 to a predetermined level;

1 37. The system defined in Claim 1 wherein the image processing
2 path comprises:
3 a forward wavelet transform;
4 a denoising processing block coupled to the forward wavelet
5 transform to perform denoising based on a given threshold;
6 a sharpening or smoothing processing block coupled to the denoising
7 processing block to sharpen or smooth coefficients based on the magnitude
8 of individual coefficients;
9 an inverse wavelet transform coupled to the sharpening or smoothing
10 processing block; and
11 a downsampling block coupled to the inverse wavelet transform to
12 downsample wavelet coefficients.

1 38. The system defined in Claim 1 further comprising an input
2 operable to receive the input image from an external source and a scanner
3 for generating the input image, wherein the input and the scanner are
4 coupled to the image processing path.

1 39. A method comprising:

2 processing an input image by enhancing the input image, including
3 applying a forward wavelet transform to create a plurality of coefficients and
4 filtering coefficients with a coefficient domain operator in a wavelet domain;
5 and
6 outputting a processed image.

1 40. The method defined in Claim 39 further comprising:
2 applying one or more wavelet-based processing blocks to coefficients
3 resulting from applying the forward wavelet transform; and
4 applying an inverse wavelet transform.

1 41. The method defined in Claim 40 wherein the forward wavelet
2 transform comprises a critically sampled wavelet transform.

1 42. The method defined in Claim 40 wherein the forward wavelet
2 transform comprises an overcomplete wavelet transform.

1 43. The method defined in Claim 40 wherein the forward wavelet
2 transform comprises a Haar wavelet transform.

1 49. The method defined in Claim 1 wherein performing denoising
2 comprises setting coefficients below the at least one given threshold to a
3 predetermined value.

1 50. The system defined in Claim 49 wherein the at least one given
2 threshold is calculated based on the presence of additive Gaussian white
3 noise in an image.

1 51. The system defined in Claim 49 wherein the at least one given
2 threshold is calculated from a series of test images.

1 52. The system defined in Claim 49 wherein the at least one given
2 threshold comprises different thresholds are applied to different levels of
3 decomposition.

1 53. The system defined in Claim 49 wherein the at least one given
2 threshold comprises different thresholds are applied to different bands.

2 sharpening or smoothing coefficients based on the magnitude of
3 individual coefficients; and
4 applying an inverse wavelet transform on the plurality of coefficients
5 after sharpening or smoothing.

1 65. The method defined in Claim 64 wherein sharpening or
2 smoothing comprises multiplying wavelet coefficients with a scale
3 dependent factor.

1 66. The method defined in Claim 65 wherein the scale-dependent
2 factor comprises:

3
$$\mu_j = R \cdot 2^{\alpha_j}$$

4 where R is a renormalization factor and α is the parameter that determines
5 the degree of sharpening or smoothing.

1 67. The method defined in Claim 64 wherein sharpening or
2 smoothing comprises normalizing coefficients.

1 68. The method defined in Claim 39 further comprising applying a
2 linear interpolation filter to wavelet coefficients.

1 69. The method defined in Claim 39 further comprising:
2 applying an inverse wavelet transform to inverse transform
3 coefficients down to a predetermined level; and
4 downsampling wavelet coefficients.

1 70. The method defined in Claim 69 wherein downsampling the
2 wavelet coefficients comprises performing either a deterministic or random
3 sampling based on coefficient size at the predetermined level.

1 71. The method defined in Claim 69 wherein downsampling
2 wavelet coefficients comprises using at least one interpolation filter based on
3 a value of a coefficient with respect to a predetermined threshold.

1 72. The method defined in Claim 71 wherein the at least one
2 interpolation filter comprises a Key's filter.

1 77. A method comprising:

2 computing a classifier;

3 selecting different denoising thresholds for halftone and text regions

4 of an image based on the classifier.

1 79. The method defined in Claim 78 wherein computing a
2 classifier comprises computing a standard deviation of wavelet coefficients
3 in different bands.

1 80. The method defined in Claim 78 wherein computing a
2 classifier comprises computing a standard deviation of wavelet coefficients
3 in different decomposition levels.

1 90. The method defined in Claim 88 wherein rescaling coefficients
2 comprises filtering LL band coefficients with a high pass filter.

1 91. The method defined in Claim 89 wherein rescaling coefficients
2 comprises filtering LL band coefficients with a low pass filter.

1 92. The method defined in Claim 84 further comprising filtering of
2 a subband at a specific level decomposition to modify the subband.

1 93. The method defined in Claim 92 further comprising filtering
2 the LL component at the largest decomposition level with a sharpening
3 filter.

1 94. The method defined in Claim 92 further comprising filtering
2 the LL component at the largest decomposition level with a smoothing filter.

1 95. The method defined in Claim 84 wherein filtering coefficients
2 comprises removing periodic patterns in a specific band by applying a filter
3 to the specific band.

